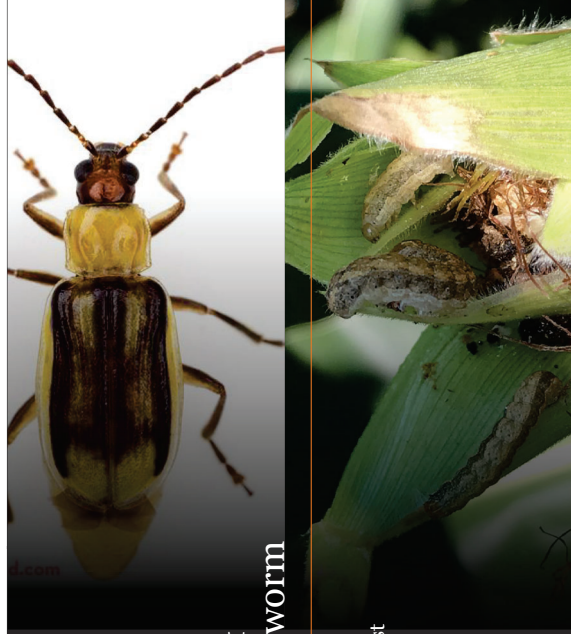


Updates on Insect Resistance: Corn Rootworm & Western Bean Cutworm

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 University of Nebraska-Lincoln
 WCREC, North Platte, NE

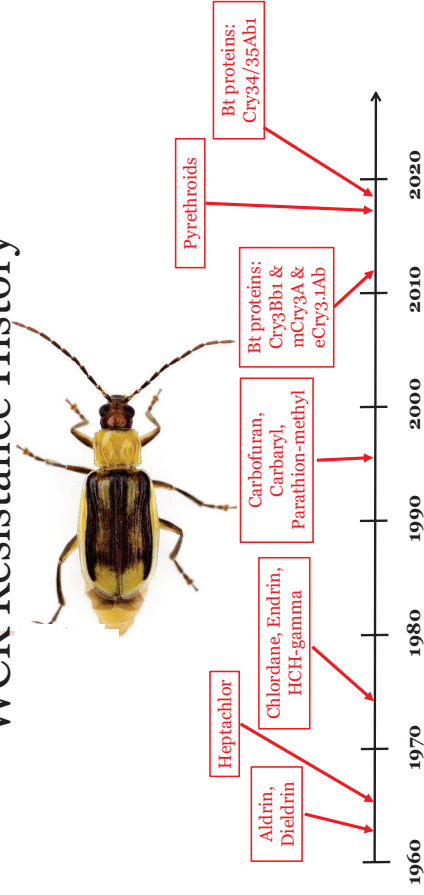


Western Corn Rootworm

- Crop rotation
- Bt traits and seed treatments
- At-plant insecticides targeting larvae
- Aerial insecticide applications for adults
- Biological controls

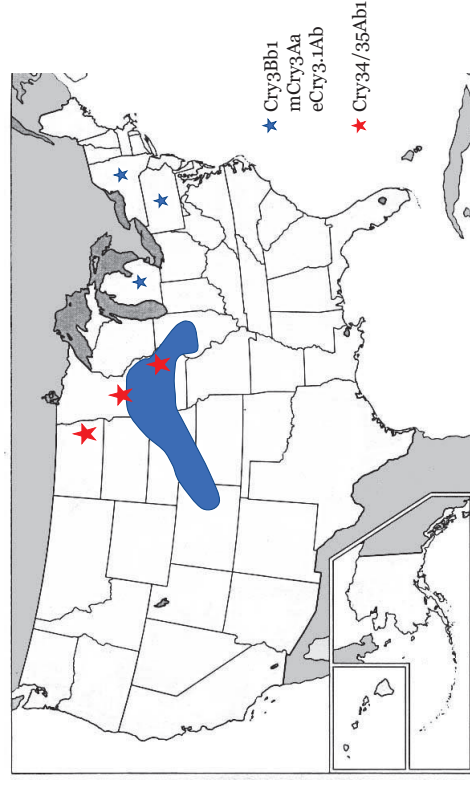


WCR Resistance History



Arthropod Pesticide Resistance Database

Areas with Confirmed Bt Resistance



Corn Rootworm-Targeting Bt Proteins (examples)

Cry3Bb1



Cry34/35Ab1



mCry3Aa



Cry3Bb1 x Cry34/35Ab1



mCry3Aa x Cry34/35Ab1



mCry3Aa x eCry3.1Ab



The Handy Bt Trait Table for U.S. Corn Production

Updated February 2020

The newest version of the table is posted at <https://www.texasinsects.org/bt-corn-trait-table.html>
 Editor: Chris DiFonzo, Michigan State University, difonzo@msu.edu Web host: Pat Porter, Texas A&M University

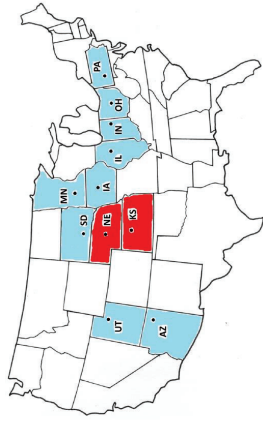
Trait packages in alphabetical order (acronym that may be used)	BT protein(s) in the trait package	Marketed for control of:											Resistance confirmed to the combination of Bt's in package (check local situation)		Herbicide Trait			Non-Bt Refuge % (cornbelt)								
		B	C	E	F	S	T	W	C	A	S	C	W	A	B	C	W		R	L	E					
AcreMax CRW	(AM) Cry1Ab Cry1F	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	CEW FAW WBC	NCR	WCR	x	x	5% in bag
AcreMax1	(AM1) Cry34/35Ab1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	ECB FAW SWB WBC	NCR	WCR	x	x	10% in bag
AcreMax Leptra	(AML) Cry1Ab Cry1F Vip3A	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	CEW FAW WBC	NCR	WCR	x	x	10% in bag
AcreMax Trisect	(AMT) Cry1Ab Cry1F mCry3A	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	CEW FAW WBC	NCR	WCR	x	x	20% ECB
AcreMax Xtra	(AMX) Cry1Ab Cry1F Cry34/35Ab1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	CEW FAW WBC	NCR	WCR	x	x	10% in bag
AcreMax Xtreme	(AMXT) Cry1Ab Cry1F mCry3A Cry34/35Ab1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	CEW FAW WBC	NCR	WCR	x	x	5% in bag
Agrisure 3010	(BR) Cry1Ab	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	CEW			x	x	20%
Agrisure 3000G1 & 3011A	(VR) Cry1Ab mCry3A	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	CEW	WCR		x	x	20%
Agrisure Vipera 3110	(VR) Cry1Ab Vip3A	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	CEW	WCR		x	x	20%

Common Characteristics of Problem Areas

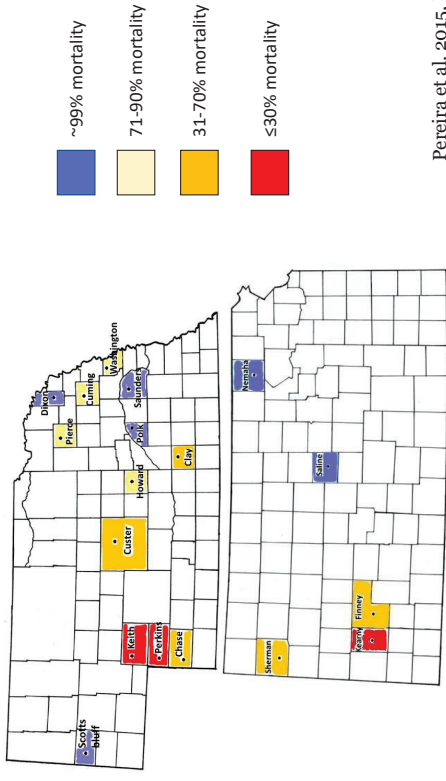
- Continuous corn
 - Intensive livestock production areas
- History of repeated use of the same, single protein Bt traits
- Moderate-severe larval rootworm injury in problem areas
- High adult WCR rootworm densities
- Increasing use of at-plant soil insecticides with trait, chemigation or aerial application to rescue Bt fields or to lower adult density

Pyrethroid Resistance Studies

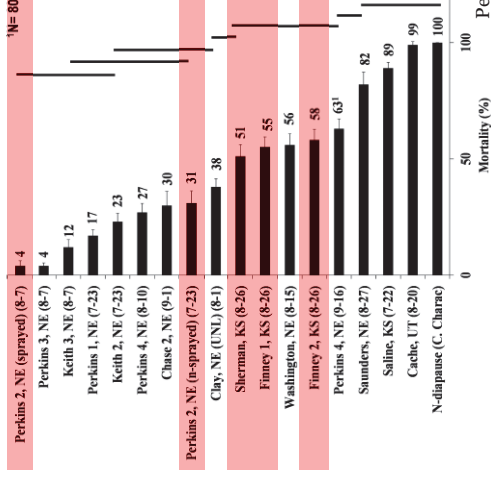
- Reports of problems controlling adult beetles with pyrethroid foliar applications (first half of the 2010's) in Nebraska and Kansas
- Test how susceptible western corn rootworm are to bifenthrin (Brigade, Capture, etc. AI)
- Establish LC₉₉ (concentration that kills 99%) for susceptible rootworm beetles
- Expose field-collected beetles to the LC₉₉ to see how many survive



Susceptibility to Bifenthrin



Pereira et al. 2015, PLoS One



Pereira et al. 2015, PLoS One

Summary of First Study

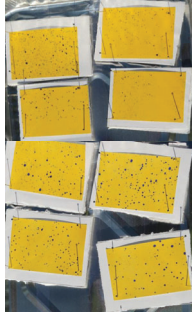
- Bifenthrin (common pyrethroid) resistance in western Nebraska and Kansas
- This first study showed that resistance to pyrethroids was emerging as a problem as early as 2014
- ❖ How does the LC_{99} used in this study relate to insecticide concentrations applied in the field? What is the level of practical resistance?

Exploring What is Really Happening in the Field

1. Determine how much insecticide AI and in what pattern reaches the target pest with an aerial application.
2. Reproduce these application characteristics in the laboratory using wind tunnel and spray chamber.
3. Test how application methods affect susceptible and resistant western corn rootworm beetles.

Measuring Spray Deposition in the Field

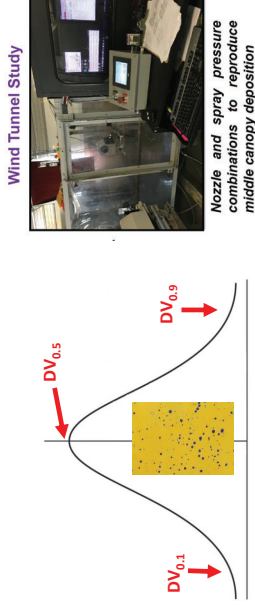
- Water sensitive papers placed at Top, Middle, and Bottom canopy
- Aerial applications made with AirTractor at 2 and 5 GPA



Souza et al. 2019, Scientific Reports

Deposition at the Middle Canopy

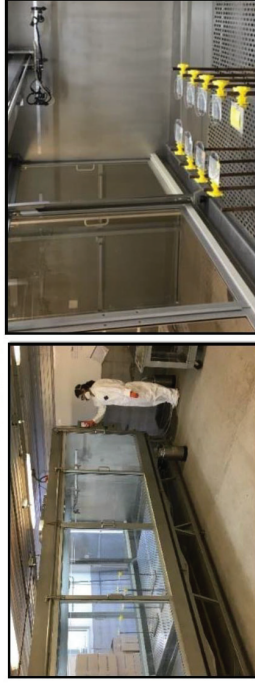
- For 2 GPA application = 1.17 GPA
- For 5 GPA application = 1.76 GPA
- 50th percentile droplet size = 299-346 μm (1/100 of an inch)



Souza et al. 2019, Scientific Reports

Reproducing Aerial Application in the Spray Chamber

Aerial Application Simulation



- Spray chamber simulating middle canopy deposition*
- ✓ Brigade 2EC lowest and highest label rates (2.1 and 6.4 oz/ac)
 - ✓ 2GPA and 5GPA
 - ✓ Petri dishes were sprayed

Souza et al. 2019, Scientific Reports

Assessing Mortality to Rootworm Beetles

Infestation and Mortality Evaluation



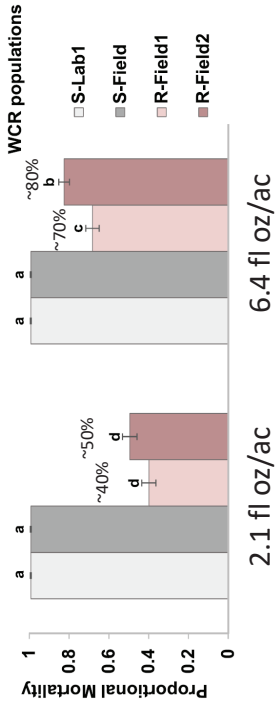
- Treated Petri dishes infested with mixed-age WCR beetles*
- ✓ Mortality after 24h

- Tested against two resistant and two susceptible beetle populations

Souza et al. 2019, Scientific Reports

Results

- Carrier volume (2 vs. 5 GPA) did not affect results
- Insecticide rate was a significant factor:



Souza et al. 2019, Scientific Reports

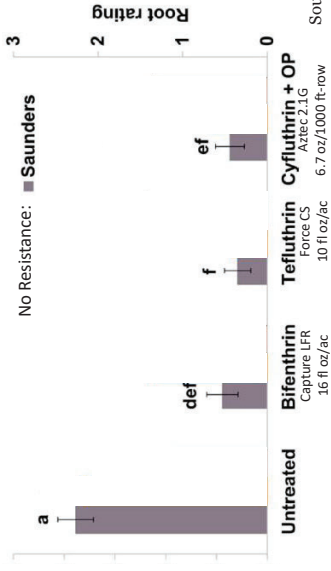
Corn Rootworm Take-Home Points

- Resistance to Cry3 Bt proteins is present in western NE and KS
- Pyrethroid insecticides no longer highly effective against WCR adults and larvae in southwest NE & KS
 - > Rotate MOA!
 - > Check AI on labels, especially for adults/larvae
- Rootworm management is not a “what is the best single trait or insecticide” situation
 - > Use of multiple tactics and rotation: crop rotation, planting effective Bt traits, judicious use of insecticides for adult or larval control, biological control
- The broad goal should be to limit both rootworm economic injury & limit the evolution of resistance



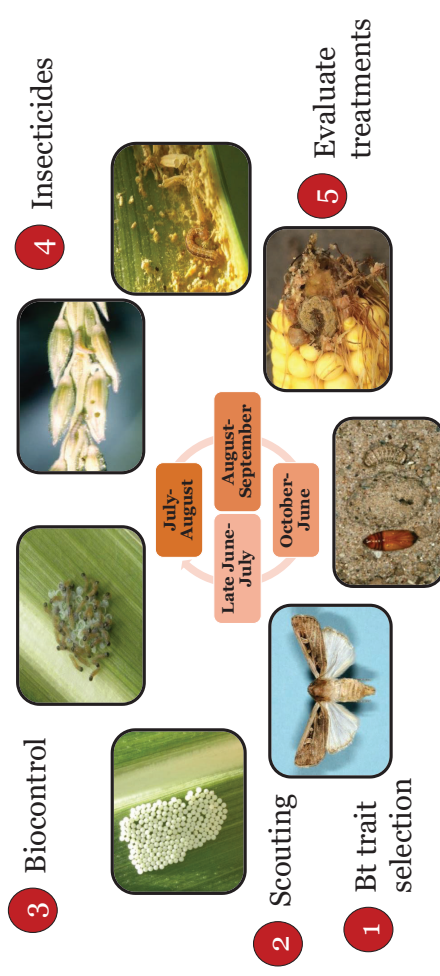
Pyrethroids In-Furrow for Larvae

- So far, experiments looked only at the adults (beetles)
 - > But is pyrethroid resistance passed on to the larvae?
 - > Unfortunately, yes– pyrethroid in-furrow at-plant products performed worse in areas with resistant adult rootworms

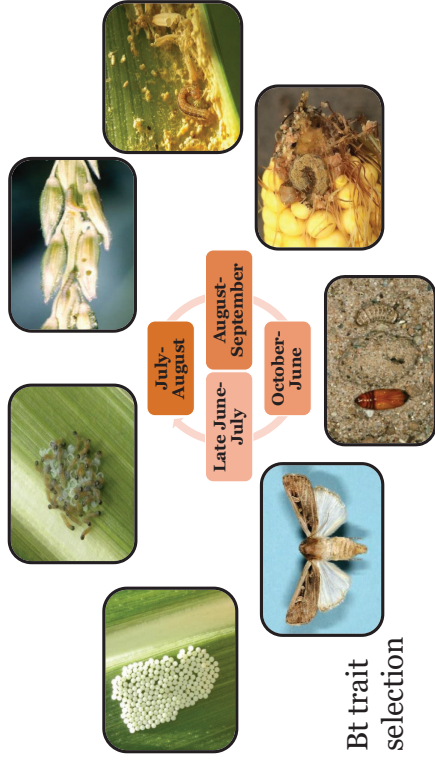


Souza et al. 2020, Pest Management Science

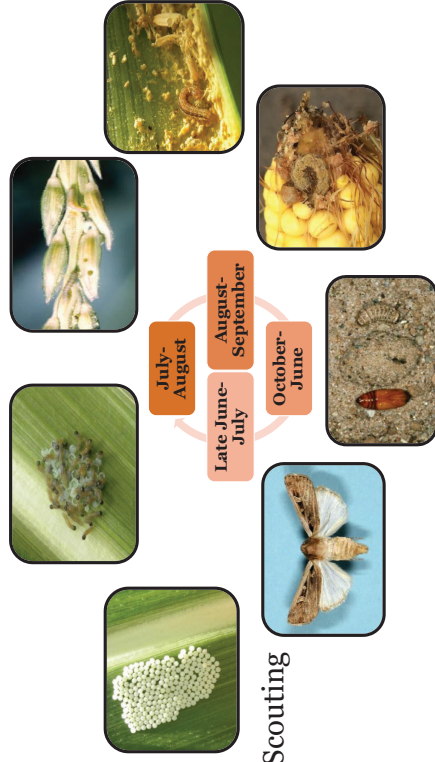
Western Bean Cutworm



Western Bean Cutworm

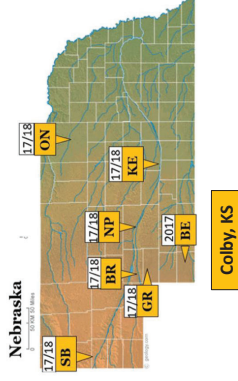


Western Bean Cutworm



Bt Trait Updates

- Not all caterpillar traits will affect WBC
- Cry1F: Herculex, SmartStax
 - > 88% of NE crop consultants reported that Cry1F Bt corn is providing less control (2014-2016)
 - > Confirmed resistance to Cry1F in Nebraska (2017-2018)
 - > WBC removed from label of all Cry1F products
- Vip3A: Viptera, Leptra, Trecepta
 - Traits provide very good control, but resistance is always on the horizon



Colby, KS

[Handy Bt Trait Table](#)

Archibald et al. 2017, *Journal of IPM*

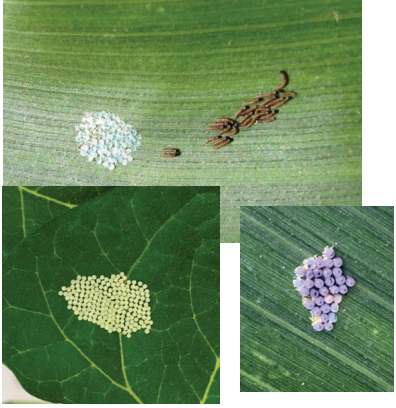
Coates et al. 2020, *Journal of Economic Entomology*

When to Start Scouting

- Be informed about moth flight predictions from the degree-day model:
 - CropWatch article
 - [AgriTools App](#)
- Monitor moth flights through trapping:
 - UNL black light trap data [online](#)
 - Green bucket and pheromone

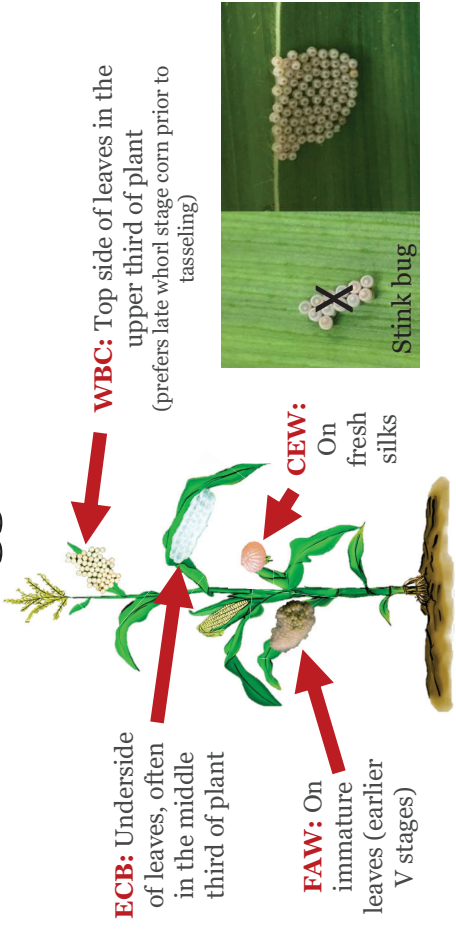
Threshold	2021 Actual	Record
5% Flight	6670	614
10% Flight	715	616
25% Flight	786	619
50% Flight	790	623
75% Flight	773	627
90% Flight	717	71
95% Flight	720	73
		81

Western Bean Cutworm Scouting



- Select 20 plants in 5 different parts of each field (100 plants)
 - ❖ Or reduce # of plants using [WBC Speed Scout App](#)
- Examine the surface of corn leaves in the upper third of the plant for egg masses and the tassel, leaf axils, and ear tips for larvae
- Treatment is recommended if 5-8% of plants are infested with eggs or larvae
- If corn is at milk stage (R3) before eggs are laid, no treatment is needed

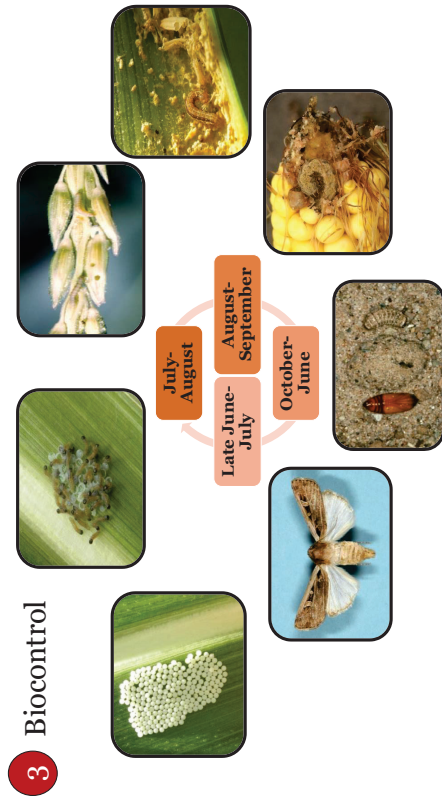
WBC Egg Identification



How Often Should You Scout?

- A lot of the older recommendations say that eggs hatch in approximately 5-7 days
- Egg hatching time highly dependent on temperature:
 - 4-6 days at average 79.9 °F
 - 5-9 days at average 75.6 °F
- Scouting once per week may be missing a lot of egg masses; every 4-5 days can be more accurate
- Crop growth stage is critical
 - Moths prefer late whorl to early tasseling plants
 - Larvae that hatch and have access to fresh tassel survive the best

Western Bean Cutworm



3 Biocontrol

The Good Guys At Work!



Spying on Egg Masses in the Field

- Larvae may stay near the egg mass for 12 h
- Hatching not synchronized, may take 10 h
- Neonates not disrupted by a rainstorm
- Minute pirate bugs feed on egg masses

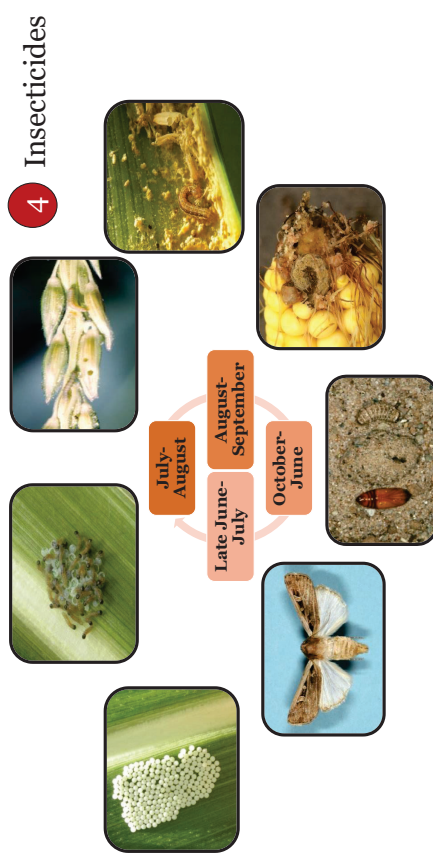


How Can You Support the Good Guys?

- Plant non-crop, perennial, diverse habitat around crop fields
- Use thresholds to avoid unnecessary insecticide spraying; choose products that are less toxic to beneficials

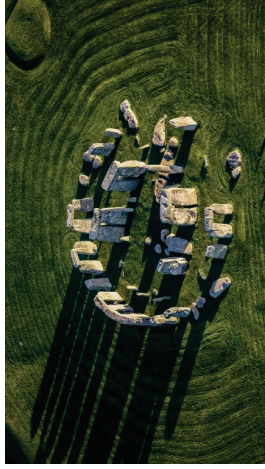


Western Bean Cutworm



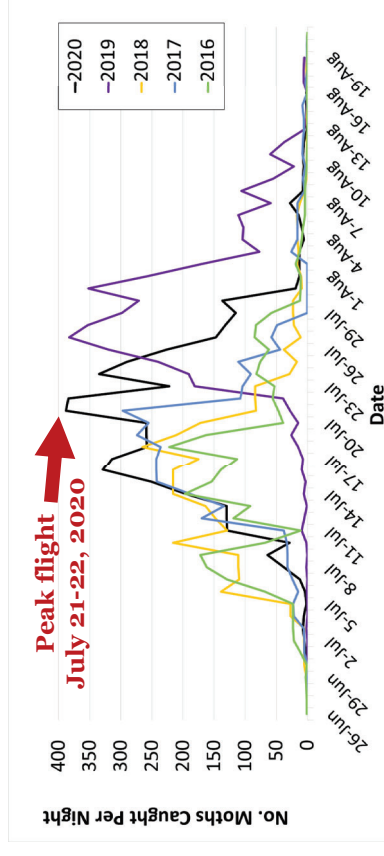
Insecticides: Timing

- Threshold of >5-8% of plants infested has been met through scouting
- Plants are at ~95% tassel
- Egg masses are purple to hatching
- Peak of moth flight has been reached
- Favorable environmental conditions



Perfect alignment of the stars?? Does the “perfect” timing actually exist?

North Platte Moth Flight Over Time:



Insecticides: Product Choice

- Between 2014-2016, 88% of NE crop consultants treated at least once for WBC
- Pyrethroids comprise 80% of insecticides used
 - Bifenthrin and zeta-cypermethrin most common AI's: Brigade, Hero, Mustang Maxx, Capture
- 51% of crop consultants reported decreased pyrethroid efficacy



Archibald et al. 2017, *Journal of IPM*

WBC Pyrethroid Study Results

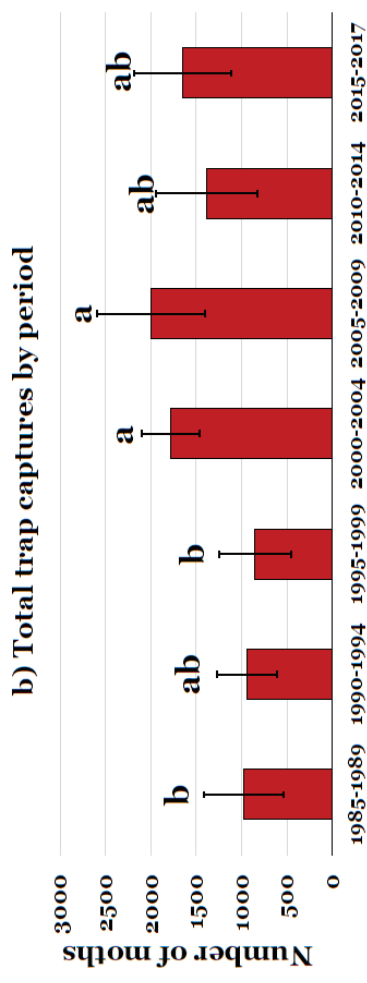
- Nebraska WBC less susceptible to bifenthrin than Canadian population
- No differences between NE locations
- Resistance ratios reflect partial resistance or resistance in progress
- When applications are “ideal” they are effective
- Resistance not the whole story:
 - Application timing and technique
 - Temperature or other environmental conditions
 - Pest and crop phenology



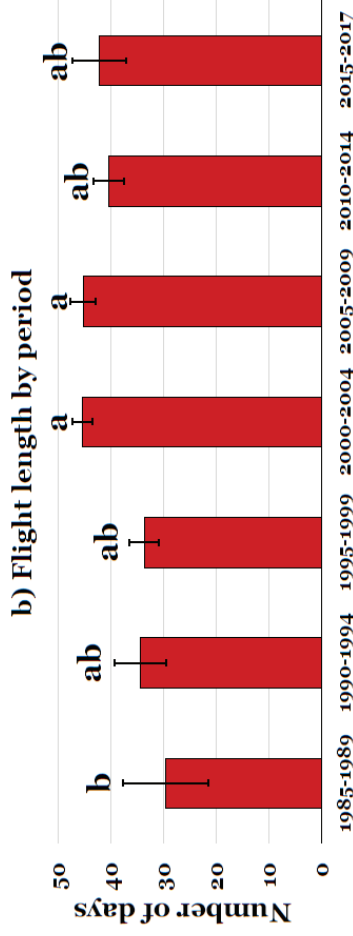
30 Years of Light Trap Data!



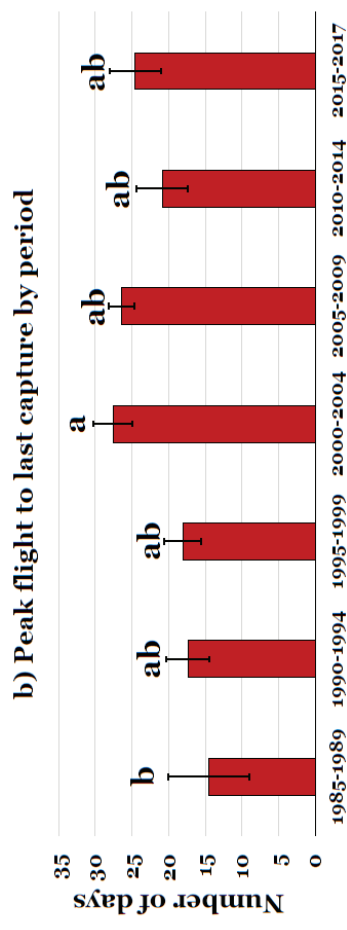
WBC Flights: Total # Increasing



WBC Flights: Length Increasing



WBC Flights: 2nd Half Longer



Why Does the 2nd Half of Flight Have Greater Impact?

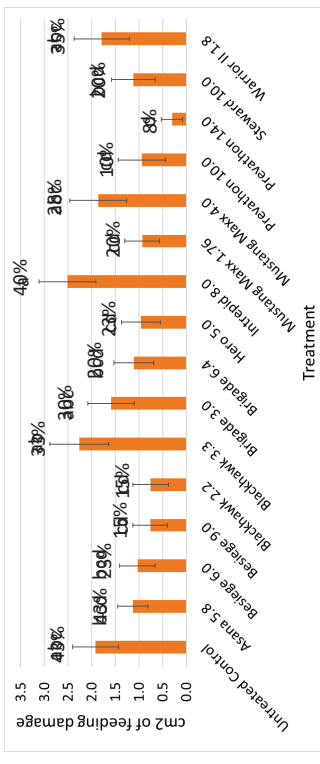


Corn tissue	Larval survival (%)
Leaf only	3.6 (± 3.0)
Leaf + Tassel	74 (± 17)
Pollen	31 (± 8)
Silk	45 (± 10)
Silk + Pollen	56 (± 10)

Paula-Moraes et al. 2012, *Environmental Entomology*

Insecticide Trials: Grant 2018

- Medium pressure (17% egg masses)
- Mixed population of WBC (72%) and CEW (28%) upon assessment of ear damage



Can insecticides kill WBC eggs?

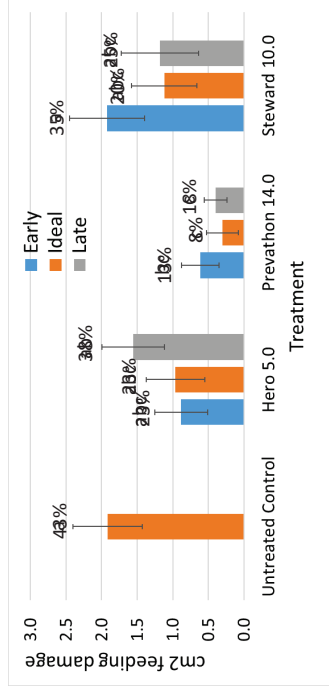


- No evidence for ovicidal effects at the low and high label rates of:
 - Mustang Maxx
 - Brigade
 - Hero
 - Prevathon
 - Steward
- But, after hatching larvae died quickly in all treatments but Steward (needs ingestion for higher efficacy)
- Lab conditions were ideal for up to 5 days of insecticide residual
- Lady beetles that ate eggs sprayed with Mustang Maxx did not die, but were severely disoriented compared to eating eggs sprayed by Prevathon



Why Does the 2nd Half of Flight Have Greater Impact?

- Early: July 17 (<50% tasseled)
- Ideal: July 24 (90% tasseled)
- Late: July 31 (100% tasseled)



Western Bean Cutworm Take-Home Points

- Western bean cutworm has evolved resistance to the Cry1F Bt protein (a trait found in Herculex and SmartStax), leaving Vip3A as the sole highly effective protein
- There are many beneficial insects that help out by eating WBC eggs and larvae
- Insecticide applications should be made only when the economic threshold has been met and timing is carefully considered
- Insecticide product choice is important to minimize resistance and risk to beneficial insects

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